ENERGY CONSERVATION GUIDELINES FOR SEWAGE WORKS

October 1977

Ministry of the Environment

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GUIDELINES

FOR ENERGY CONSERVATION

IN THE DESIGN OF SEWER SYSTEMS AND SEWAGE TREATMENT FACILITIES

IN THE PROVINCE OF ONTARIO

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PREFACE

In view of today's "energy crisis" the Ministry of the Environment has prepared the following guidelines for the conservation of energy in the design of sewage systems. The people of North America have generally not been energy conscious in the past, due to the abundance and the low cost of energy. It is evident from all reports on future energy sources and costs, that all Canadians must learn to conserve energy.

As the approving body of sewage systems and as an owner and/or operator of many sewage systems in Ontario, the Ministry of the Environment urges designers of such facilities to consider carefully the associated energy consumption and related costs. The energy crisis is having an ever increasing impact on the design, construction and operation of sewage works. The changing relationships of costs and availability of energy resources may now produce different answers from those that appeared only a few years ago. Designers and operators must re-examine existing programmes and adopt approaches and design criteria to ensure that facilities which are constructed will be economical, from an energy usage point of view, for the life of the facility. This does not mean that conservation of energy should be pursued "at all costs", at least for the present time. For example, it would be economically wrong to design a facility with much higher capital costs and higher non-energy-related operating costs in order to obtain a minor reduction in energy consumption.

These guidelines are the first publication by the Ministry of the Environment with regard to energy conservation in the design of sewage works systems. They were deliberately kept general to the degree that one might say that many of the items discussed are what should have been considered in the past by any conscientious engineer regardless of any energy crisis. While this is true, it is doubtful that the majority of North American engineers have been placing enough emphasis on energy

conservation in their designs.

If these guidelines make designers aware that the energy crisis is real, will continue indefinitely and will indeed escalate in the future, the Ministry will have achieved a substantial part of its objective in issuing these guidelines.

As this Ministry's policy on energy conservation is developed, it is anticipated that these general guidelines will be replaced by more detailed ones pertaining specifically to the design of the various unit processes and facilities.

1.0 INTRODUCTION

When evaluating various alternatives for a sewage system, the designers should consider both capital and operating costs. For this evaluation the operating costs should include energy, chemical, manpower and maintenance costs. The comparison of the present value costs of the various options should include capitalization of the operating costs for each alternative. Where analysis shows economic similarity among alternatives, the alternative with the least energy requirement should be selected. Because of the level of estimation required in prediction of future chemical, power and labour costs as well as the general inflation rate, it is recognized that difficulty will be experienced in establishing the capitalized value of the operating costs.

2.0 PROJECTION OF POWER COST INCREASES

It is very difficult to project the future increases in power costs since many factors (e.g. source, availability, volume requirements and pattern of usage) must be considered.

Various reports reviewed indicate that power costs are expected to increase at the rate of 12-18% per year for the next few years. This rate of increase is then expected to reduce to approximately 5-6% per year by the late 1980's and early 1990's. These estimated increases were premised on a general inflation rate of 5-6% per year.

Based on these assumptions for power costs and projected increases, the 20-year (lifetime) operating power costs should be capitalized by multiplying the present-day annual costs by a factor of approximately "18". (See Appendix 'A' for the derivation of this factor). This factor must be reviewed annually and adjusted accordingly.

3.0 PROJECTION OF LABOUR COSTS

Annual labour costs for the 20-year period should be estimated based on a projected escalation rate. These annual costs should then be converted to a present value and capitalized.

For example, assuming an escalation rate of 6% per year for the first ten years and 5% per year for the last ten years of a 20-year design period and assuming an interest rate of 9% per year over the total design period, it is shown that the capitalized operating costs correspond to the present annual operating costs multiplied by a factor of approximately "15". (See Appendix 'B' for the derivation of this factor).

4.0 ENERGY CONSERVATION IN THE DESIGN OF SEWAGE FACILITIES

In view of future high energy costs, the Ministry of the Environment will require designers to minimize power consumption on all future projects wherever practicable. In this regard, the following guidelines for the design of sewage facilities should be considered:

4.1 Sewers

4.1.1 Sewers should be constructed at minimum practical depth to reduce capital costs and pumping and/or operating costs. Subject to the topography, minimum sewer grades should be adopted and sewer invert drops at manholes should only be incorporated into the design where hydraulically justified.

4.1.2 The number and size of pumping stations should be kept to a minimum. Wherever practical, inverted siphons, above grade sewers, (e.g. in the vicinity of a sewage treatment plant) etc., should be considered to eliminate the need for pumping stations.

4.1.3 Repumping should be eliminated wherever feasible.

4.1.4 Overall sewer system studies should include economic analyses of various layout alternatives taking into consideration both capital and operating costs.

4.1.5 Where unusually high flows are established entering the existing sewer system from infiltration and/or illegal connections, corrective measures should be considered for the existing sewer system as an alternative to extending pumping stations and/or sewage treatment works.

4.2 Forcemains

4.2.1 The sizing of forcemains should be based on capital and associated pumping power costs.

4.2.2 For future peak flows, the construction of a second forcemain or flow equalization facilities (if practical) should be considered to reduce hydraulic losses and thus conserve energy.

4.3 Pumping Stations

4.3.1 The wet well high water elevation should be designed as high as practicable. Consideration should be given to intermittently surcharging the incoming sewer if surcharging will not result in basement flooding or other unacceptable servicing conditions.

4.3.2 Pumping equipment is usually responsible for the highest percentage of energy consumption in a sewage system. It is therefore mandatory to consider the respective efficiencies during pump selection. In the evaluation for the pump selection, the designer should calculate the capitalized value of each 1% of efficiency of the overall pumping unit based on hydro costs and frequency of use. This amount should be applied to the differences in pump efficiencies and considered along with the various capital costs.

4.3.3. Incoming flows to pumping stations vary considerably and the designer quite often attempts to match discharge rates to the influent flow rates. This approach results in the need for variable speed pumping units and possibly an inefficient installation. The efficiency and installation of variable speed pumps at different flows should be compared to an installation with constant speed pumps and a combination of variable speed and constant speed pumps. The comparison should take into account the sensitivity of the discharge point to any surging associated with fixed speed pump operation.

4.3.4 When variable speed units are used, energy recovery devices should be given serious consideration.

4.3.5 Although there is some advantage to having pumping units of the same size, a proper selection of pumps with different head-capacity characteristics operating individually or in selected combinations according to flow conditions, could result in a more efficient operation.

4.4. Sewage Treatment Plants

4.4.1 Hydraulics

The hydraulic losses through a treatment plant should be kept to a minimum. Wherever possible, the need for a pumping station to supply the treatment facility should be eliminated. In some cases it may be more economical to lower the plant thereby increasing the capital costs to avoid a pumping station.

It is recognized that some designers prefer to be liberal with the hydraulic losses through a plant to provide future flexibility for expansion. This approach must be clearly justified and documented.

4.4.2 Bar Screens and Comminutors

Manually cleaned bar screens should be considered at small plants.

Mechanically cleaned bar screens should be considered at large plants in lieu of comminutors considering the lower energy consumptions.

4.4.3 Grit Removal Facilities

Manually cleaned grit channels with proportional weirs should be used at small plants.

The use of mechanical grit removal equipment should be limited to intermediate size and large plants. The relative energy requirements of the various systems available should be considered when selecting this equipment.

The capital and operating costs of detritors and aerated grit chambers should be carefully analyzed.

4.4.4 Primary and Secondary Settling Tanks

While the designer must consider the capital costs associated with a circular versus a rectangular tank design for the settling tank components, he should also be aware that circular tanks generally necessitate higher energy requirements than rectangular tanks due to the hydraulic losses associated with each configuration. However, the designer must also take into account the relative operating costs associated with alternate designs as well as the process requirements of the total system.

4.4.5 Aeration

The selection of mechanical aeration or diffused air aeration will depend on the size and process adopted for the plant. When evaluating what type of aeration system to select, the following factors should be considered:

a) size and location of plant;

b) kWh/kg. of BOD removed;

c) oxygen transfer capabilities;

d) minimum kg O_2/kWh;

e) the need for covering tanks and heating;

f) building space and heating requirements for air blower building area;

g) use of pure oxygen systems.

4.4.6 Nitrification

Where water quality limitations require nitrification and/or denitrification of the sewage flow, the designer must compare both the capital and operating costs associated with the physical-chemical and biological removal process alternatives available.

4.4.7 Filtration

Where limitations on effluent quality require the inclusion of filtration as a unit process, the filter system should be selected to minimize any pumping requirements associated with the head loss through the filters and the backwash water facilities.

4.4.8 Chemicals

Some of the factors to be considered with respect to chemical usage are as follows:

- where a choice of chemicals is possible to accomplish a required treatment process, the energy demands in the production of the chemicals should be taken into consideration when evaluating these alternatives;

- All chemicals required for the operation of sewage treatment plants should be used economically in view of the high energy costs associated with their production;

- The water used for chlorine injectors should be kept to a minimum;

- The use of pressure reducing valves and other energy wasting devices should be minimized.

4.4.9 Effluent Pumping

The use of an effluent pumping station in lieu of a raw sewage pumping station should be given serious consideration at a treatment facility for the following reasons:

- Normally only the highest water level, possibly the flood level, of the receiving river or lake is considered. This can result in an uneconomical design since this discharge level occurs during a short period of time during a given year or maybe only once every twenty years;

- There may be a requirement to provide a high degree of dispersement due to the quality of the receiving water body resulting in high outfall sewer hydraulic losses only at peak flows.

4.4.10 Equalization Facilities

Similar to the provision of effluent pumping, it may be economical and feasible to provide equalization storage ahead of a sewage treatment plant. Once again, both capital and operating costs must be considered. Operating costs for cleaning and provision of aeration and mixing should also be included in the evaluation.

4.4.11 Activated Sludge Pumping

The following factors should be considered in the sludge pumping system design:

- The total pumping head should be kept to a minimum;

- Sludge flow from the secondary settling tanks should not be controlled by throttling devices unless such arrangements can be economically justified;

- Waste activated sludge, which normally is 1% of the incoming sewage flow, should be pumped separately if the static discharge head is higher than that for the return of the activated sludge.

4.4.12 Sluge Dewatering and Disposal

During the past five years designers have considered many alternatives for the treatment and disposal of sewage sludge due to the

regulations regarding land disposal and air pollution. Some of the alternatives available for sludge dewatering are:

a) thermal conditioning followed by vacuum filtration;

b) thermal conditioning followed by filter presses;

c) anaerobic digestion with chemical conditioning and vacuum filtration;

d) chemical conditioning followed by filter presses;

e) chemical conditioning followed by centrifuges;

f) chemical conditioning followed by belt filters;

g) solar sludge drying beds (summer use only).

Disposal of sludge after dewatering can be accomplished by land disposal or incineration.

The choice of sludge dewatering-disposal system will generally be unique to the application under consideration. Plant size, general economic considerations and site location are among the many factors that must be analysed.

When incineration is contemplated the following aspects should be considered:

- The production of an autogenous sludge cake is important since there is a significant fuel requirement associated with the incineration of sludge cake which has a low heat yield (i.e. high water content). Consequently, the water content of the dewatered sludge should be considered;

- The heat recovery potential of the alternative systems.

Where economical, anaerobic and aerobic digestion should also be considered. The capital costs, oxygen requirements associated with aerobic digestion, use of methane gas produced from anerobic digestion and solids concentrations should be included in this analysis.

4.4.13 Building Design

a) Ventilation

The amount of outside air or treated air used for ventilation should be provided in accordance with the requisite regulations. In many cases, the amount of outside air provided through filtering devices exceeds that required under the regulations. The use of interior air should be considered with a view to economy.

b) Heating

Consideration should be given to site layout, building orientation and building design to minimize energy use. For example, buildings can be designed without a north-west exposure to reduce the impact of the prevailing winter winds. Earth removed from excavations can be integrated into a landscape plan to provide wind buffers and insulation. The buildings can be constructed of low heat loss construction materials and be provided with a significant amount of insulation.

- Waste heat from pumps, motors, engines, boilers and lights should be taken into consideration.

- Hydro "demand" charges should be considered. This will influence the type of heating from an economical point of view.

- Devices should be considered to recover waste heat.

- Alternatives to conventional heating methods (e.g. the use of solar energy) should be considered.

c) Lighting

Lighting levels in the buildings at a sewage plant should be determined by task. High-lighting should be provided for specific tasks with lower levels for general lighting. Lighting systems should use the most efficient

fixtures and lamps. Use lights only when needed. Switches should be provided to shut off the lights when not needed.

5.0 SUMMARY

It is evident that energy costs will increase significantly in the future. Consequently, it is imperative that designers of municipal sewage facilities consider not only capital costs but also capitalized annual operating costs with an emphasis on energy conservation. The evaluation of all viable alternatives for the provision of sewage treatment facilities and the selection of equipment should consider the future cost of energy.

APPENDIX 'A'

6.0 Calculation of "Present Value Multiplier" for Projected Power Costs

6.1 The projected rates of escalation of bulk power costs were obtained from Ontario Hydro, covering the 20-year period from 1977 to 1996. These increases refer to inflated dollars (or "dollars-of-the-year") costs, and assume a general rate of inflation of about 6%/year up to 1986 and 5%/year thereafter.

6.2 Applying the above escalation rates, the cost of one arbitrary unit of energy (i.e. $1.00 worth @ 1977 rates) was calculated for each year up to 1996. See Table 1, Column (4). These figures are all in inflated "dollars-of-the-year".

6.3 The present value of these future yearly amounts was then tabulated, assuming interest rates of 7, 8, 9 and 10% per annum (Columns (5), (6), (7) and (8).

6.4 Each of these columns of present values was then summed to arrive at a 20-year total present value multiplier. Each of these totals represents the number of dollars which would have to be invested in 1977 at the respective interest rate, to pay for $1.00 worth of electrical energy during 1977 and an equal amount of energy, at escalating rates, each year up to and including 1996.

6.5 An interest rate approximating the general increase in productivity (Gross National Product) in addition to the general rate of inflation is generally

available. Since the Ontario Hydro projections are based on the assumption of 6 and subsequently 5% inflation rates, it was assumed that an average interest rate of 9% (an increase in general productivity of 3 and 4% respectively) was available for this study. The resulting present value multiplier is then 17.74, which has been rounded off to 18.

6.6 It is accepted that prediction of the inflation, productivity and interest rates is at best nebulous. However, this approach does result in a common basis for comparison purposes and can be beneficial if these assumptions are clearly understood.

APPENDIX 'B'

7.0 Calculation of "Present Value Multiplier" for Projected Maintenance Costs

7.1 The rate of escalation of labour and other maintenance costs is assumed to equal approximately the general rate of inflation, which in turn is assumed to be 6%/year up to 1986 and 5% thereafter.

7.2 Applying the above rates, calculations have been performed in the same manner as for Power Costs and the results are in Table 2.

7.3 The 20-year total present value at an interest rate of 9% (i.e. 15.22) has then been rounded to arrive at a present value multiplier of <u>15</u>.

TABLE 1

8.0 CAPITALIZED COST OF ELECTRICAL ENERGY

Year	Cost @ 1977 Rates	Percent Rate Increase*	Cost @ Increased Rate	Present Value at Interest Rate of: 7%	8%	9%	10%
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1977	1.00	-	1.00	1.00	1.00	1.00	1.00
78	1.00	13.0	1.13	1.06	1.05	1.04	1.03
79	1.00	12.0	1.265	1.10	1.08	1.07	1.04
80	1.00	7.0	1.354	1.10	1.08	1.05	1.02
1981	1.00	8.0	1.463	1.11	1.08	1.04	1.00
82	1.00	9.0	1.594	1.14	1.09	1.04	0.99
83	1.00	8.0	1.722	1.15	1.08	1.03	0.97
84	1.00	7.0	1.842	1.15	1.07	1.01	0.94
85	1.00	5.0	1.934	1.13	1.04	0.97	0.90
1986	1.00	4.0	2.012	1.09	1.01	0.93	0.85
87	1.00	5.0	2.112	1.07	0.98	0.89	0.82
88	1.00	5.0	2.218	1.05	0.95	0.86	0.78
89	1.00	5.0	2.329	1.03	0.92	0.83	0.74
90	1.00	5.0	2.445	1.01	0.90	0.80	0.71
1991	1.00	5.0	2.567	1.00	0.87	0.77	0.68
92	1.00	6.0	2.722	0.99	0.86	0.75	0.65
93	1.00	3.0	2.803	0.95	0.82	0.71	0.61
94	1.00	5.0	2.943	0.93	0.79	0.68	0.58
95	1.00	4.0	3.061	0.91	0.77	0.65	0.55
1996	1.00	5.0	3.214	0.89	0.75	0.62	0.53
20-Year Total Present Value =				20.86	19.19	17.74	16.39

*Increase over previous year. Ref. bulk power cost projections by Ontario Hydro.

9.0

TABLE 2

CAPITALIZED COST OF MAINTENANCE

Year	Cost @ 1977 Rates	Percent Rate Increase*	Cost @ Increased Rate	Present Value at Interest Rate of: 7%	8%	9%	10%
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1977	1.00	-	1.00	1.00	1.00	1.00	1.00
78	1.00	6.0	1.06	0.99	0.98	0.97	0.96
79	1.00	6.0	1.124	0.98	0.96	0.95	0.93
80	1.00	6.0	1.191	0.97	0.95	0.92	0.89
1981	1.00	6.0	1.262	0.96	0.93	0.89	0.86
82	1.00	6.0	1.338	0.95	0.91	0.87	0.83
83	1.00	6.0	1.419	0.95	0.89	0.85	0.80
84	1.00	6.0	1.504	0.94	0.88	0.82	0.77
85	1.00	6.0	1.594	0.93	0.86	0.80	0.74
1986	1.00	6.0	1.689	0.92	0.84	0.78	0.72
87	1.00	5.0	1.774	0.90	0.82	0.75	0.68
88	1.00	5.0	1.863	0.88	0.80	0.72	0.65
89	1.00	5.0	1.956	0.87	0.78	0.70	0.62
90	1.00	5.0	2.054	0.85	0.76	0.67	0.60
1991	1.00	5.0	2.156	0.84	0.73	0.64	0.57
92	1.00	5.0	2.264	0.82	0.71	0.62	0.54
93	1.00	5.0	2.377	0.81	0.69	0.60	0.52
94	1.00	5.0	2.496	0.79	0.67	0.58	0.49
95	1.00	5.0	2.621	0.78	0.66	0.56	0.47
1996	1.00	5.0	2.752	0.76	0.64	0.53	0.45
20-year Total Present Value =				17.89	16.46	15.22	14.09

*Based on assumption that labour and other maintenance costs will escalate at the same rate as general inflation.